FINAL REPORT

PROPELLANT VARIABILITY ASSESSMENT

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By

Thomas P. Tytula
and
Kristin Schad

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Contract NAS8-36955
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Quality Engineering Research Laboratory
The University of Alabama in Huntsville

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INTRODUCTION

This is the final report covering efforts under Contract NAS8-36955, Delivery Order 117. The original objective of this task was to determine whether rocket propellant density and modulus can be reliably measured using non-destructive ultrasonic measurement techniques. The planned effort called for the investigation of HTPB propellant variability to make extensive use of data generated by Aerojet Propulsion Division. Supposedly, arrangements for this had been made by the Marshall Space Flight Center (MSFC) sponsor; however, after the delivery order was issued, personnel changes at Aerojet resulted in these data becoming unavailable. In an effort to perform the required task, an extensive search of the available open literature was undertaken. This search did not provide adequate information to satisfy the delivery order scope and the effort was terminated by mutual agreement of the MSFC sponsor and the principal investigator. Summarized below are the approach and the few results gleaned from the search.

APPROACH

The first step was to obtain a working knowledge of current propellant processing and testing procedures. This was to be accomplished by literature search and discussion with knowledgeable personnel at MFSC, the U. S. Army Missile Command, and appropriate contractors. This would be followed by analysis and characterization of historical data which was to be made available through MSFC. The analysis would concentrate primarily on process parameters, type of test data (full scale or subscale, destructive or non-destructive), propellant type, attributes of the instrumentation used in taking the data, environmental conditioning, and physical properties of the propellant. The objective of this analysis was to obtain insight into possible rela-

tionships and dependencies between propellant physical properties, such as density and modulus, and process conditions.

Based on the results of the analysis of historical data, additional experiments would be designed to provide any additional information needed to determine whether ultrasonic techniques can be used to adequately estimate propellant mechanical properties. Exploratory data analysis and regression analysis were the proposed methods for defining preliminary relationships. Model validation was to be attempted by comparing forecast to actual results for some subsets of experimental data.

Assuming that an empirical model resulted from these efforts, an experiment was to be designed that would validate the model. Actual performance of the experiment was not a part of this effort; rather, it would be relegated to a follow-on task.

RESULTS

The literature search was conducted at Redstone Scientific Information Center, Redstone Arsenal, Alabama. Two searches were performed - one a computer search of Defense Technical Information Center listings and the other a hand search of Scientific Technical Aerospace Reports (STAR) for the period January 1985 through January 1991, The Journal of Propulsion and Power for the period January 1985 through March 1991, and the Index of International Aerospace Abstracts from January 1988 through April 1991. As mentioned above, the information gleaned from these efforts was insufficient to permit satisfactory completion of the delivery order scope. Pertinent reports found are as follows.

1. Thrasher, Durwood; "State of the Art of Solid Propellant Rocket Motor Grain Design in the United States"; AD No. P006019. (This report deals with solid rocket propellant grain structural integrity assurance, including

materials characterization, structural analysis, and structural capability verification.)

2. Little, Robert; "An Investigation Into Specimen size Bias on Propellant Mechanical Properties"; U. S. Army Missile Command Report AMSMI/TR-RD-PR-90-1, 1990

3. Marsh, Barbara; "The Effects of Specimen Size on the Mechanical Properties of Composite Propellants"; U. S. Army Missile Command Report AMSMI/TR-RD-PR-87-6, 1987.

4. Marsh, B. and D. Martin; "Moisture Effects on Structural Reliability of the PERSHING II First Stage Propellant Grain"; U. S. Army Missile Command Report AMSMI/RK-84-7-TR.

5. "A Study of Selected Parameters in Solid Propellant Processing"; STAR N87-26094.

6. "Effects of Geometric and Material Nonlinearities on the Propellant Grains Stress Analysis"; IAA A89-11129.

7. Veit, P. W., L. G. Landuk, and G. J. Svob; "Experimental Evaluation of As - Processed Propellant Grains"; Journal of Propulsion and Power; Volume 1, Number 6, November-December, 1985; pp 494-7. (This paper concludes that structural integrity evaluations cannot be solely based on data obtained from carton (sub-scale) samples of propellant. Experimental evaluation of as-built propellant grains is necessary due to deviations from expected behavior caused by manufacturing and aging. Factors include carton-motor bias, gradients in propellant and bond properties, orientation effects, liner properties variation, and combined effects.)

Two reports were obtained directly from Aerojet Propulsion Division. Both of these were entitled "Mechanical Properties of the Peacekeeper Stage II Propellant Bond System". They were written by Robinson and Svob.

These two papers contained the most useful information found during the entire search. Conclusions are summarized below:

Bond properties exhibit cyclic behavior; shear and peel strength values are typically lower in the summer than they are in the winter.

Bond tensile strength indicated a general upward trend in the more recently produced motors.

Within carton strength, strain, and tangent modulus variability was generally greater than carton - to - carton variability from the same propellant batch.

There was a statistically significant difference in means among lot combinations for all properties. This variability appeared to be to be influenced by a change in raw material lots.

Test condition generally has no effect on propellant properties.

Samples trimmed from the aft-end of motors tend to indicate harder propellant; i. e., higher strength and modulus and lower strain than observed in laboratory carton samples. Variability was also greater - this was attributed to bondline proximity, specimen orientation, propellant flow patterns, etc.

CONCLUSIONS AND RECOMMENDATIONS

Sufficient information to formulate a model for measuring modulus from ultrasonic measurements was not found; furthermore, it was not possible to conduct an experimental investigation given the change in contractor personnel. Some information on the variation in propellant physical properties due to processing and other factors was obtained from the literature. This information indicates that there is an environmental effect (summer versus winter), a time effect that could be the result of a learning process, an effect due to raw materials, and a casting effect (aft-end trim samples and within carton variability).

The original objective of determining the feasibility of using ultrasonic methods to measure solid propellant still has merit. The problem with this particular task was in the approach. It is now known that sufficient information to hypothesize a model form is not available in the existing available literature. It is recommended that an experimental program be undertaken to determine feasibility. This program should include adequate resources to procure subscale and full scale samples and perform both ultrasonic and physical measurements with associated data analysis. Definition of experimental factors requires additional investigation.

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16. Abstract

Efforts to determine whether rocket propellant density and modulus can be reliably measured using non-destructive ultrasonic techniques are reported. The objective was not achieved, primarily due to the approach undertaken.

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Solid Rocket Propellant, Density, Modulus

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